

NOTES

HEART FAILURE

GENERALLY, WHAT IS IT?

PATHOLOGY & CAUSES

- A complex clinical syndrome characterized by the heart's inability to effectively fill and/or eject (pump) blood
- **Stroke volume (SV):** volume (mL) of blood pumped by heart per contraction
- **Cardiac output (CO):** volume of blood pumped by heart per minute (L/min)
 - $CO = SV \times \text{heart rate}$
- **Preload:** amount of blood in left ventricle before contraction
- **Afterload:** stress on the ventricular wall during systole
 - $\uparrow$ systemic resistance, $\uparrow$ blood viscosity, aortic valve stenosis, ventricular dilation $\rightarrow \uparrow$ afterload
- **Inotropy:** cardiac contractility
- **Ejection fraction (EF):** % of blood leaving heart during each contraction

$$\text{EF} = \left(\frac{\text{stroke volume}}{\text{end diastolic volume}} \right) \times 100$$

- **Frank-Starling mechanism:** loading ventricle with blood during diastole, stretching out cardiac muscles $\rightarrow$ more forceful contraction; $\uparrow$ SV during systole

Heart failure (HF) with reduced ejection fraction (HFrEF)

- Systolic HF; "pump dysfunction"
- **Causes:** $\downarrow$ contractility/force of contraction (e.g. myocardial infarction, myocarditis), $\downarrow$ blood supply to the heart (e.g. coronary artery disease), $\uparrow$ afterload (e.g. hypertension), impaired mechanical function (e.g. valve disease)

- Normal preload, $\downarrow$ contractility (inotropy; force of contraction) $\rightarrow$ inadequate emptying of ventricles during systole $\rightarrow \downarrow EF \leq 40$ (HFrEF); often also have some degree of diastolic dysfunction

HF with preserved ejection fraction (HFpEF)

- Diastolic HF; "filling dysfunction"
- **Causes:** restrictive cardiomyopathy (e.g. amyloidosis, sarcoidosis), valve disease, hypertension
- Ventricles noncompliant and unable to fill during diastole $\rightarrow \uparrow$ filling pressures $\downarrow$ preload, normal contractility $\rightarrow \downarrow SV \rightarrow$ preserved $EF \geq 50$ (HFpEF)

TYPES

- Biventricular heart failure
 - Left, right failure; systolic/diastolic
- Cor pulmonale
 - Heart failure secondary to any cause of pulmonary arterial hypertension
- Left-sided heart failure
 - Impaired ability of the left ventricle to maintain adequate cardiac output without an increase in left-sided filling pressures
- Right-sided heart failure
 - Impaired ability of the right ventricle to deliver of blood flow to the pulmonary circulation and $\uparrow$ right atrial pressure
- Classification based on structure and symptoms
 - ACC/AHA HF Stages, NYHA Classes (see table)

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CLASSIFICATION OF HEART FAILURE

ACC/AHA HF STAGE	NYHA FUNCTIONAL CLASS
A. At risk for HF without structural heart disease or symptoms	
B. Structural heart disease but without HF	I. Asymptomatic
C. Structural heart disease with prior or current HF symptoms	II. Symptomatic with moderate exertion III. Symptomatic with minimal exertion
D. Refractory HF requiring advanced interventions (e.g. implantable cardioverter defibrillator, biventricular pacing, left ventricular assist device)	IV. Symptomatic at rest

ACC - American College of Cardiology
AHA - American Heart Association
NYHA - New York Hospital Association

RISK FACTORS

- **Cardiac disorders:** ischemic heart disease, valvular heart disease, hypertension, LV hypertrophy, peripartum cardiomyopathy, myocarditis, congenital heart disease, chronic tachyarrhythmias
- **Other chronic diseases:** hypertension, diabetes, obesity, chronic lung disease, infiltrative diseases (e.g. amyloidosis)
- **Toxins:** cigarette smoking, ethanol, cardiotoxic medications (e.g. doxorubicin, amphotericin B); illicit drugs (e.g. amphetamines, cocaine)
- **High-output states:** thyrotoxicosis, anemia
- ↑ age

COMPLICATIONS

- Cardiogenic shock
- Biventricular heart failure
 - Left/right-sided HF precursor/complication of each other

- Arrhythmias
- End organ damage: due to lack of perfusion
- Liver damage (congestive hepatopathy)
- Exacerbation
 - See mnemonic
 - Certain drugs may exacerbate HF; e.g. NSAIDs, excessive doses of beta blockers, calcium channel blockers, cyclophosphamide



MNEMONIC: FAILURE

Exacerbation of Heart failure

Forgot medication
Arrhythmia/Anemia
Ischemia/Infarction/Infection
Lifestyle (e.g. too much salt)
Upregulation of CO (e.g. pregnancy, hyperthyroidism)
Renal failure
Embolism (e.g. pulmonary)

SIGNS & SYMPTOMS

- **High filling pressures:** pulmonary edema, dyspnea, orthopnea, exercise intolerance, paroxysmal nocturnal dyspnea (PND), basilar crackles, tachypnea, jugular venous distention (JVD), hypoxemia, fatigue, peripheral edema, hepatomegaly, S3
- **Low cardiac output:** tachycardia, hypotension, cool extremities, ↓ pulse pressure, ↓ urine output, ↓ appetite

DIAGNOSIS

DIAGNOSTIC IMAGING

Chest X-ray

- Detects cardiomegaly, chamber and vessel enlargement, pulmonary congestion, presence of pericardial and pleural effusions

Doppler echocardiography

- Evaluates hemodynamics related to in valvular and biventricular function

Right heart (pulmonary artery) catheterization

- Measures CO (cardiac index), filling pressures, pulmonary capillary wedge pressure (PCWP)

MRI

- Visualizes ventricular volumes, mass, presence of myocardial remodeling

LAB RESULTS

- ↑ B-type natriuretic peptide (BNP) and/or N-terminal pro-BNP
- ↑ serum creatinine and blood urea nitrogen (BUN) indicates glomerular filtration rate ↓ GFR due to hypoperfusion
- ↑ serum total bilirubin and aminotransferase indicates congestive hepatopathy from right-sided HF
- ↑ serum lactate if cardiogenic shock
- Exercise testing: six-minute walk test and/or a cardiopulmonary exercise test measuring oxygen uptake (Vo₂) evaluates exercise capacity

OTHER DIAGNOSTICS

- History and physical examination identifying characteristic symptoms, evidence of fluid retention and/or hypoperfusion and functional impairment due to cardiac dysfunction

ECG

- Identifies contributing rhythm disturbances

ACUTE HEART FAILURE CLASSIFICATION

		IS CONGESTION PRESENT?	
		NO	YES
IS PERFUSION LOW?	NO	Warm & Dry (Compensated) PCWP normal CI normal	Warm & Wet (Congested) PCWP elevated CI normal
	YES	Cold & Dry (Low flow state) PCWP low/normal CI decreased	Cold & Wet (Decompensated) PCWP elevated CI decreased

TREATMENT

MEDICATIONS

- Individualized in accordance with New York Heart Association (NYHA) class, EF, comorbidities
- Angiotensin converting enzyme (ACE) inhibitor or angiotensin II receptor blockers (ARB)
- Beta-blocker (carvedilol, bisoprolol, metoprolol ER)
- Aldosterone agonist
- Mineralocorticoid receptor antagonist (HFpEF)
- Acute decompensation
 - See mnemonic



MNEMONIC: POND

Acute decompensation

Position (upright) +/- positive pressure ventilation (e.g. BiPAP)

Oxxygen

Nitrates

Diuretics

OTHER INTERVENTIONS

- Lifestyle modifications
 - Low dietary salt, exercise as tolerated, smoking cessation, minimize alcohol intake
- Ventricular assist device (VAD)
- Implanted defibrillator
- Biventricular pacemaker for resynchronization

SURGERY

- Heart transplant
 - Considered in NYHA class of III or IV despite maximized medical and resynchronization therapy

COR PULMONALE

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PATHOLOGY & CAUSES

- Right ventricular hypertrophy, dilation, and/or dysfunction due to pulmonary hypertension secondary to pulmonary disease (e.g. chronic obstructive pulmonary disease (COPD), pulmonary fibrosis), upper airway obstruction (e.g. obstructive sleep apnea, obesity-hypoventilation syndrome), or chest wall irregularities (e.g. kyphoscoliosis)
- Acute cor pulmonale develops in the setting of a sudden volume and/or pressure overload in the right side of the heart; e.g. massive pulmonary embolism
- $\uparrow$ pulmonary vascular resistance $\rightarrow$ $\uparrow$ pulmonary circuit afterload $\rightarrow$ $\uparrow$ right ventricular workload $\rightarrow$ right ventricular hypertrophy or dilatation $\rightarrow$ impaired right ventricular function and failure $\rightarrow$ $\uparrow$ right atrial pressure $\rightarrow$ fluid back-up into venous circulation $\rightarrow$ peripheral edema

RISK FACTORS

- Presence of parenchymal or vascular lung disease, chronic airway obstruction
- Smoking

- Recent surgery, hypercoagulable states ($\uparrow$ risk of pulmonary embolism)

COMPLICATIONS

- RV failure
- Liver dysfunction

SIGNS & SYMPTOMS

- Dyspnea, chest pain, peripheral edema, jugular venous distension, hepatomegaly

DIAGNOSIS

DIAGNOSTIC IMAGING

Chest X-ray

- Visualizes right ventricular hypertrophy, distended pulmonary vasculature, pulmonary edema

Echocardiography

- Detects structural and functional changes of right ventricle; estimates right ventricular systolic pressures

MRI

- Visualizes right ventricular hypertrophy, right atrial enlargement, tricuspid valve dysfunction regurgitation, retrograde flow

Cardiac catheterization

- ↑ elevated central venous pressure, ↑ right ventricular, end-diastolic pressure, evidence of underlying pulmonary disease

TREATMENT**MEDICATIONS**

- Supplemental oxygen
- Loop diuretic

SURGERY

- Heart-lung transplant for resistant cor pulmonale

OTHER INTERVENTIONS

- Treat underlying disease process
- Lifestyle
 - Low dietary salt, exercise as tolerated, smoking cessation

DIASTOLIC HEART FAILURE

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PATHOLOGY & CAUSES

- A clinical syndrome characterized by failure of the heart to pump sufficient blood to meet the metabolic needs of the body due to ↓ ventricular filling
- HF with preserved ejection fraction (HFpEF)
- Filling dysfunction
 - Stiff, non-compliant ventricle → ↓ ventricular relaxation → ↑ end diastolic pressure → ↑ resistance to filling → ↓ preload → EF ≥ 50, ↓ SV, ↓ CO → pulmonary congestion

RISK FACTORS

- ↑ age, restrictive cardiomyopathy (e.g. amyloidosis, sarcoidosis); hypertrophic cardiomyopathy, long-standing hypertension, valve disease (especially aortic stenosis), CAD, diabetes, obesity

COMPLICATIONS

- Arrhythmias, pulmonary embolism, pulmonary hypertension, right ventricular failure

SIGNS & SYMPTOMS

- Fatigue, dyspnea, orthopnea, exercise intolerance, pulmonary rales, JVD

DIAGNOSIS**DIAGNOSTIC IMAGING****Chest X-ray**

- Cardiomegaly; pulmonary vascular congestion; enlargement of right atrium, ventricle, and pulmonary arteries

Doppler echocardiography

- Altered mitral flow velocity, ↑ LVEDP, LV hypertrophy with concentric remodeling, LA enlargement, ↑ pulmonary artery systolic pressure (PASP)

LAB RESULTS

- ↑ BNP/NT-proBNP

TREATMENT

MEDICATIONS

Alleviation of symptoms

- Diuretics; antihypertensives
 - Beta blockers, ACE inhibitors, ARBs, aldosterone antagonists

OTHER INTERVENTIONS

- Manage contributing factors and associated conditions
- Lifestyle modifications
 - Smoking cessation, ↓ sodium intake, weight management, ↓ alcohol intake

LEFT HEART FAILURE

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PATHOLOGY & CAUSES

- A clinical syndrome due to an alteration of structure and/or function of the left ventricle (LV) resulting in ↓ cardiac output, pulmonary congestion, and ↓ peripheral perfusion
- Categorized according to left ventricular ejection fraction (LVEF)
 - Systolic HF: ↓ LVEF ≤40 percent (HFrEF)
 - Diastolic HF: preserved LVEF (HFpEF)
- ↓ cardiac output → backup of blood into left atrium → pulmonary circulation → ↑ pressure in pulmonary capillaries → pulmonary edema → ↓ gas exchange, dyspnea
- Neurohormonal compensatory mechanisms
 - RAAS and adrenergic activation → renal salt and water retention + vasoconstriction → ↑ contractility, ↑ circulating volume → ↑ CO, ↑ organ perfusion
 - Adverse effects of compensation: ↑ afterload, ↑ LV workload, LV remodeling
 - Natriuretic peptide secretion occurs in response to compensatory mechanisms and atrial stretch → diuresis, natriuresis, partial RAAS inhibition

RISK FACTORS

- Coronary artery disease, infiltrative disease (e.g. amyloidosis, hemochromatosis) → cardiomyopathy
- Hypertension, aortic stenosis → ↑ afterload
- Mitral or aortic regurgitation → ↑ preload
- Exposure to toxins → myocardial damage
- Arrhythmias → ↓ filling, ↓ ineffective contractions
- age > 60
- Obesity
- Diabetes mellitus/metabolic syndrome

COMPLICATIONS

- Pulmonary edema, pulmonary hemorrhage (congested capillaries burst), pleural effusion, renal insufficiency

SIGNS & SYMPTOMS

- Exertional dyspnea, orthopnea; (PND), pulmonary edema (frothy, pink-tinged sputum), bibasilar rales, cough, nocturia, restlessness, confusion. S3/S4

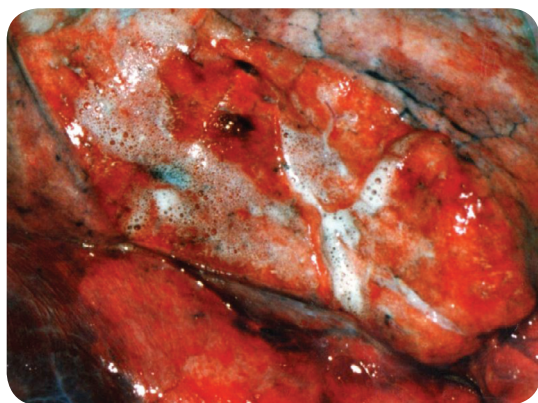


Figure 9.1 The gross pathological appearance of pulmonary edema. Exerting pressure on the lung parenchyma causes frothy white fluid to exude from it.

DIAGNOSIS

LAB RESULTS

- ↑ BNP/NT-proBNP

DIAGNOSTIC IMAGING

Chest X-ray

- Cardiomegaly, pulmonary vascular congestion, enlargement of right atrium, ventricle, and pulmonary arteries

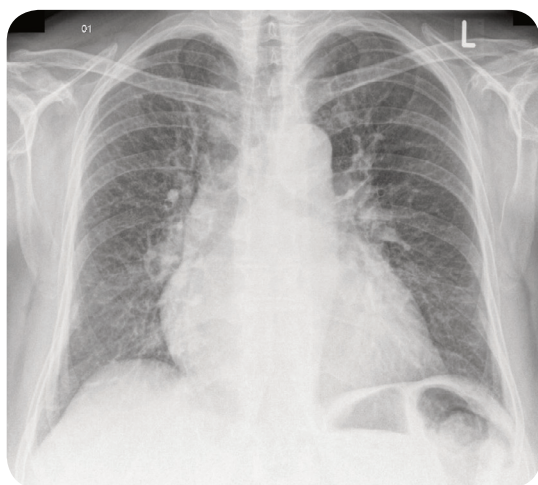


Figure 9.2 A plain chest X-ray image demonstrating pulmonary edema. The vessels at the hila are prominent and there are numerous Kerley B lines.

Echocardiography

- LV hypertrophy with eccentric remodeling, ↑ LVEDP, LA enlargement, ↑ PASP

OTHER DIAGNOSTICS

- ECG
 - Identifies contributing rhythm disturbances

TREATMENT

MEDICATIONS

- Diuretics, beta blockers, ACE inhibitors, ARBs, ARNI, hydralazine/nitrate combination, aldosterone antagonists
- Acute decompensation
 - See mnemonic



MNEMONIC: POND

Acute decompensation

Position (upright) +/- positive pressure ventilation (e.g. BiPAP)

Oxygen

Nitrates

Diuretics

MEDICATIONS

- Diuretics, beta blockers, ACE inhibitors, ARBs, ARNI, hydralazine/nitrate combination, aldosterone antagonists
- Acute decompensation
 - See mnemonic

SURGERY

- Heart transplant

OTHER INTERVENTIONS

- Manage contributing factors and associated conditions
- Lifestyle modifications: smoking cessation, ↓ sodium intake, weight management, ↓ alcohol intake
- Cardiac rehabilitation
- Implantable cardioverter-defibrillator (ICD)
- Ventricular assist device

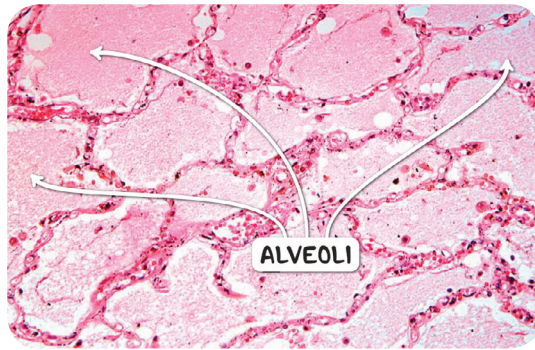


Figure 9.3 The histological appearance of pulmonary edema. There is flocculent fluid within the alveolar spaces.



Figure 9.4 Pitting edema in an individual with left-sided heart failure.

RIGHT HEART FAILURE

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PATHOLOGY & CAUSES

- A clinical syndrome due to an alteration of structure and/or function of the right ventricle (RV) leading to suboptimal delivery of blood flow to the pulmonary circulation and/or elevated venous pressures
- ↑ venous pressure → systolic volume overload
- ↑ RV workload (most often due to pulmonary congestion secondary to LV failure) → RV hypertrophy → ↓ pumping ability

CAUSES

- Left-sided heart failure, associated pulmonary edema (most common cause), right ventricular infarction, bacterial endocarditis, pulmonic valve stenosis, cardiomyopathy

COMPLICATIONS

- Eventual failure of left side of heart
- Tricuspid regurgitation
- Congestive hepatopathy
- Cardiac cachexia
 - Nausea, vomiting, anorexia, and diffuse abdominal pain due to abdominal venous congestion → weight loss

SIGNS & SYMPTOMS

- JVD, hepatojugular reflux, fatigue (related to poor gas exchange), exercise intolerance, peripheral edema, hepatosplenomegaly, ascites, S3/S4

DIAGNOSIS

DIAGNOSTIC IMAGING

Chest X-ray

- Cardiomegaly, pulmonary vascular congestion; enlargement of right atrium, ventricle, pulmonary arteries

Echocardiography

- Evaluates RV size and function; detects hemodynamic alterations

MRI

- Myocardial tissue, ventricular volume, muscle damage

Right heart catheterization

- ↑ pressure in heart chambers and lungs

LAB RESULTS

- ↑ BNP/NT-proBNP
- ↑ serum total bilirubin and aminotransferase indicates congestive hepatopathy

OTHER DIAGNOSTICS

- Clinical presentation: right heart dysfunction, rule out left heart dysfunction

ECG

- Identifies contributing rhythm disturbances

TREATMENT**MEDICATIONS**

- Loop diuretics
 - Fluid management
- Vasopressors
 - Circulatory support

OTHER INTERVENTIONS

- Treat underlying condition

**MNEMONIC: LMNOP****Treatment for Right heart failure**

Lasix
Morphine
Nitrites
Oxygen
 Vasso**P**ressors

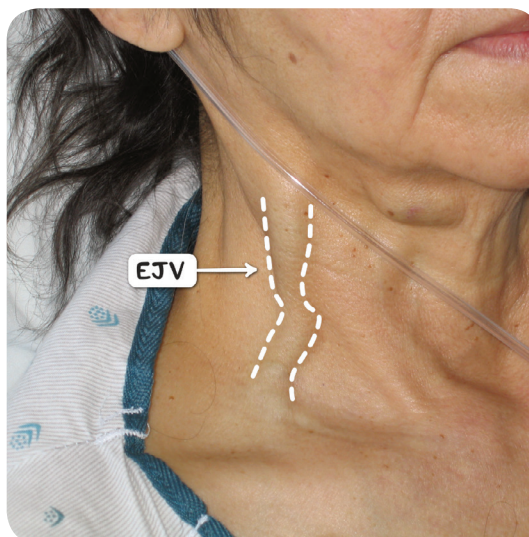


Figure 9.5 A distended external jugular vein (EJV) in an individual with right heart failure.

LEFT-SIDED VS. RIGHT-SIDED HEART FAILURE

LEFT	RIGHT
S ₃	S ₃
Pulmonary edema	Peripheral edema
Bilateral basilar rales	Hepatosplenomegaly
Orthopnea	Hepatojugular reflux
PND	JVD